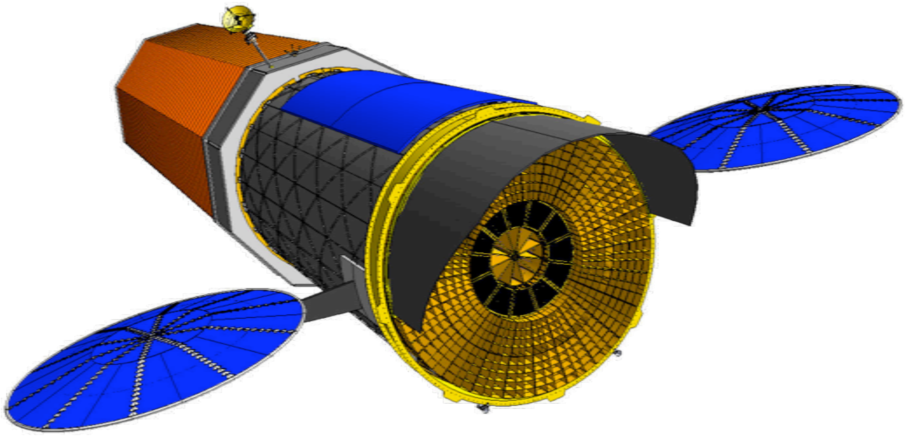
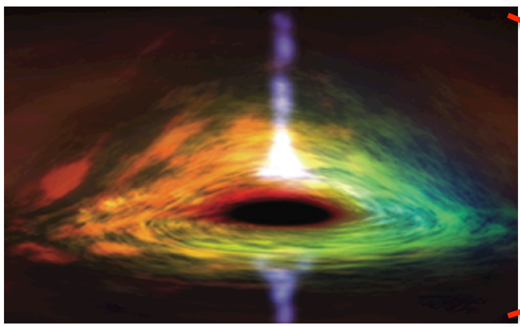


The International X-ray Observatory

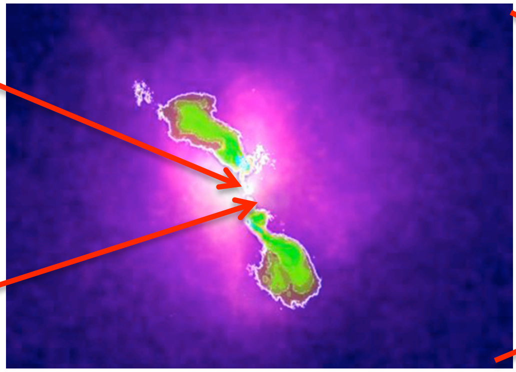
Nicholas White
NASA Project Scientist
Goddard Space Flight Center

The International X-Ray Observatory (IXO) will address fundamental and timely questions in astrophysics:

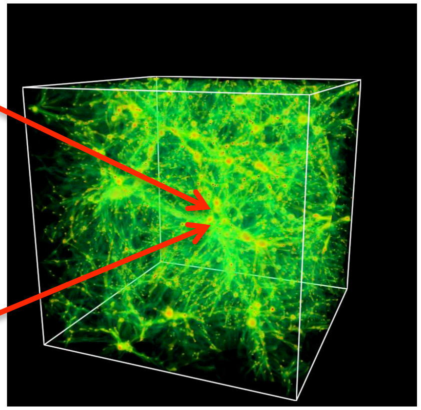
- What happens close to a black hole?
- When and how did super-massive black holes grow?
- How does large scale structure evolve?
- What is the connection between these processes?



Black Hole Accretion

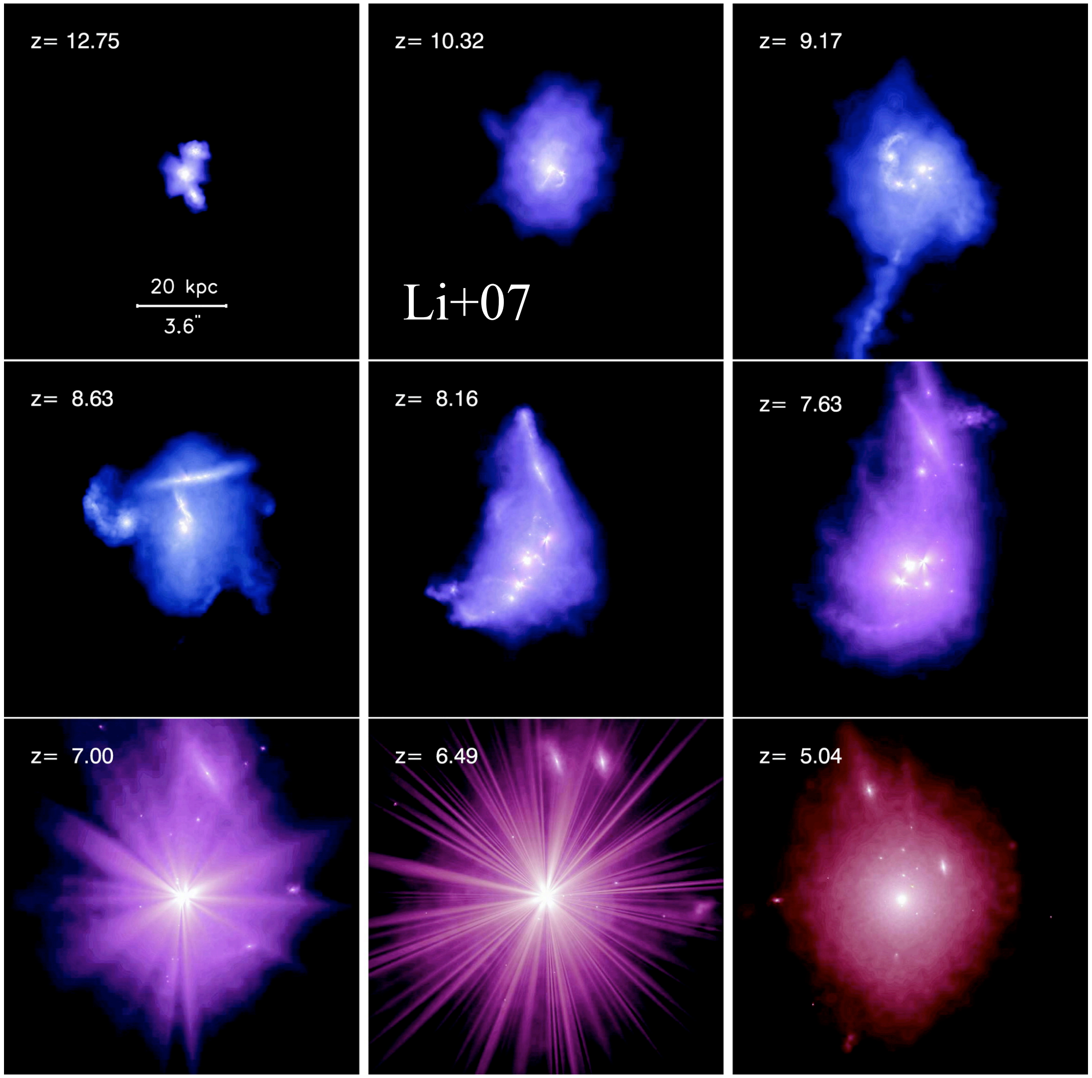


Hydra A Galaxy Cluster



Cosmic Web

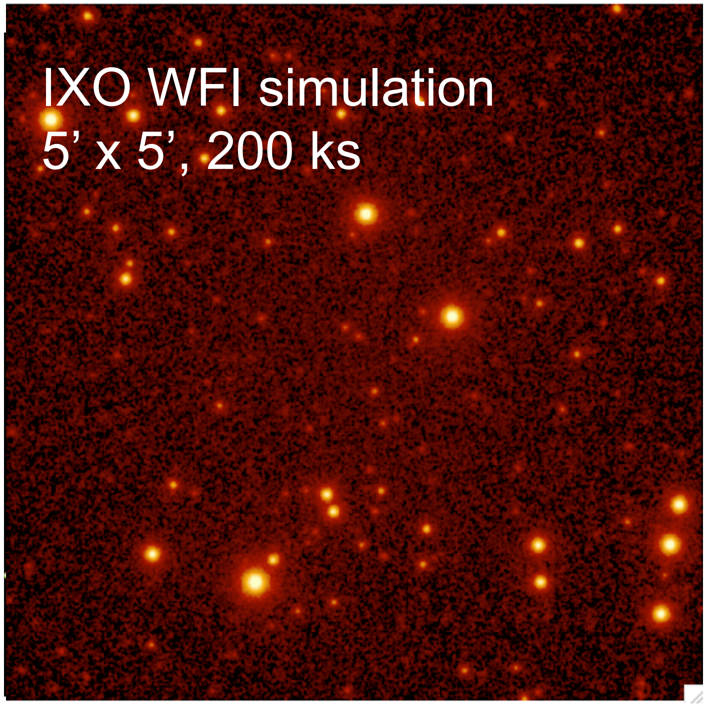
Building a ~10^9 M_{sun} BH at z ~ 6



- Gas rich major merger
- Inflows trigger BH accretion & starbursts
- Dust/gas clouds obscure AGN
- AGN wind sweeps away gas, quenching SF and BH accretion
- IXO well tuned to follow and confirm/constrain this process

Hernquist (1989)
Springel et al. (2005)
Hopkins et al. (2006)

When and How do Super-massive Black Holes Grow?



20 day exposure with Chandra will be a routine observation for IXO

Chandra and XMM-Newton deep fields reveal that super-massive Black Holes (SMBH) are common

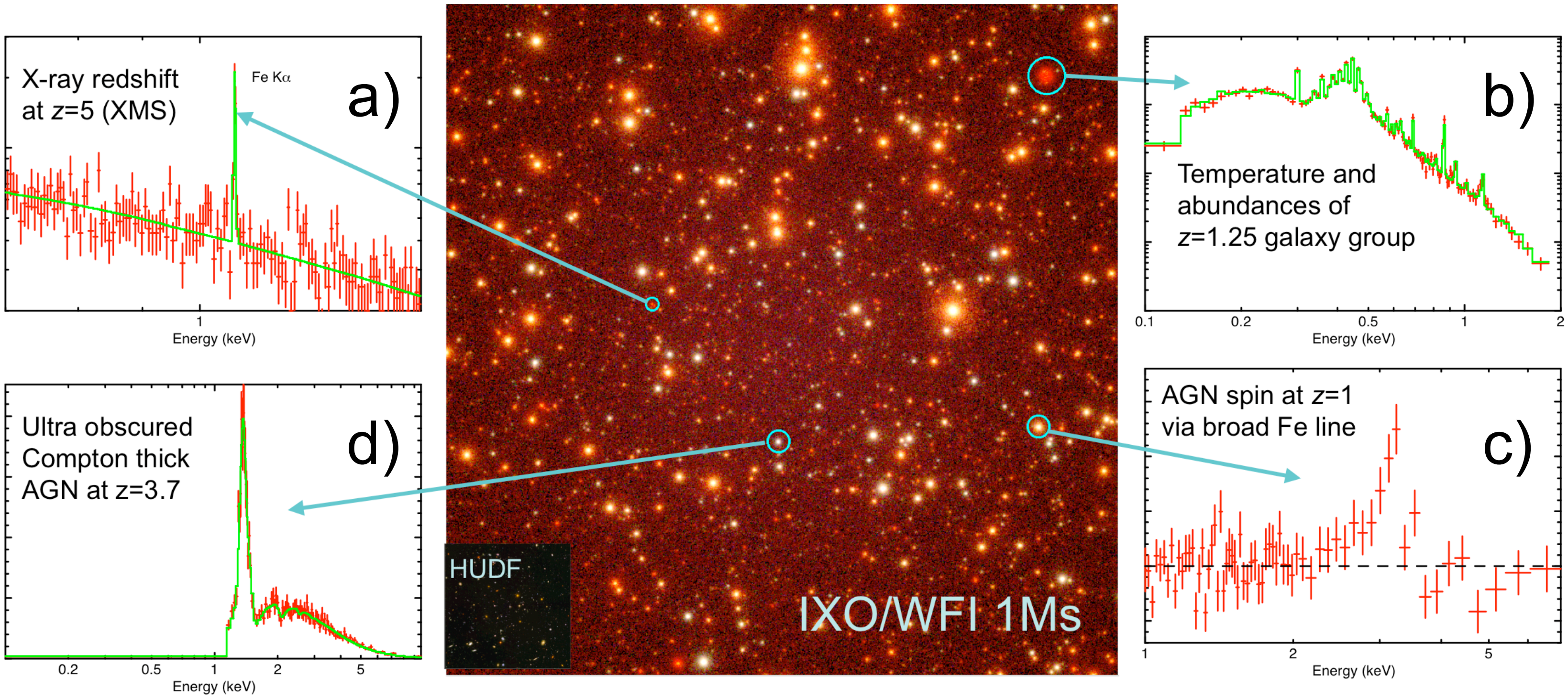
X-ray observations are a powerful tracer of their growth and penetrate obscuring material

Most of Chandra sources only have <30 counts even in 20-day deep surveys

Spectra can measure: redshift, detect multiple SMBH, estimate Eddington luminosity, black hole spin, outflows, absorption, etc..

IXO will reach the deepest Chandra fields 20 times faster, and provide spectral surveys on a square degree scale with high spectral resolution

Black Hole and Large Scale Structure Evolution with IXO

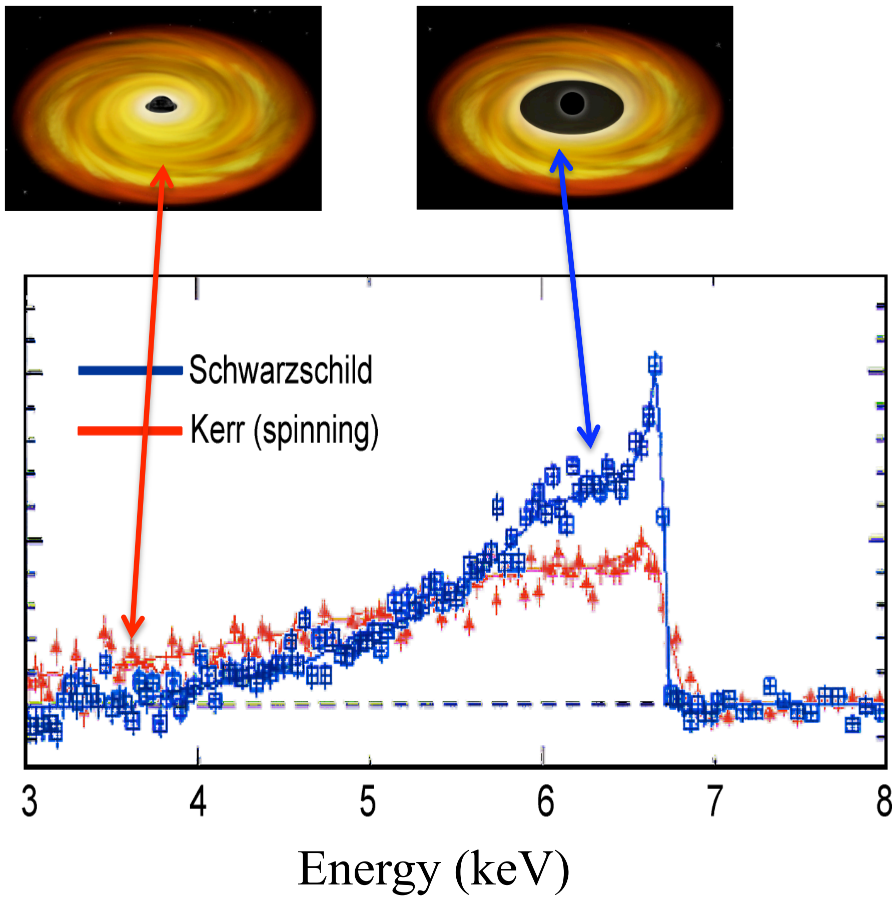


Illustrating IXO's ability to characterize the extragalactic universe:

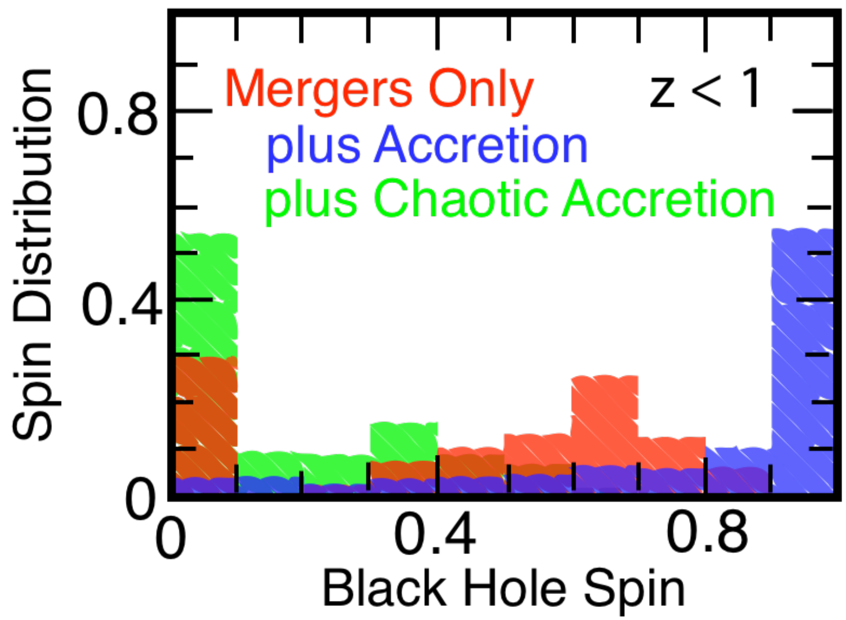
a) determine redshift autonomously in the X-ray band
b) determine temperatures and abundances even for low luminosity galaxy groups
c) make spin measurements of AGN to a similar redshift
d) uncover the most heavily obscured, Compton-thick AGN

Super-massive Black Hole Spin & Growth

Fe K Line

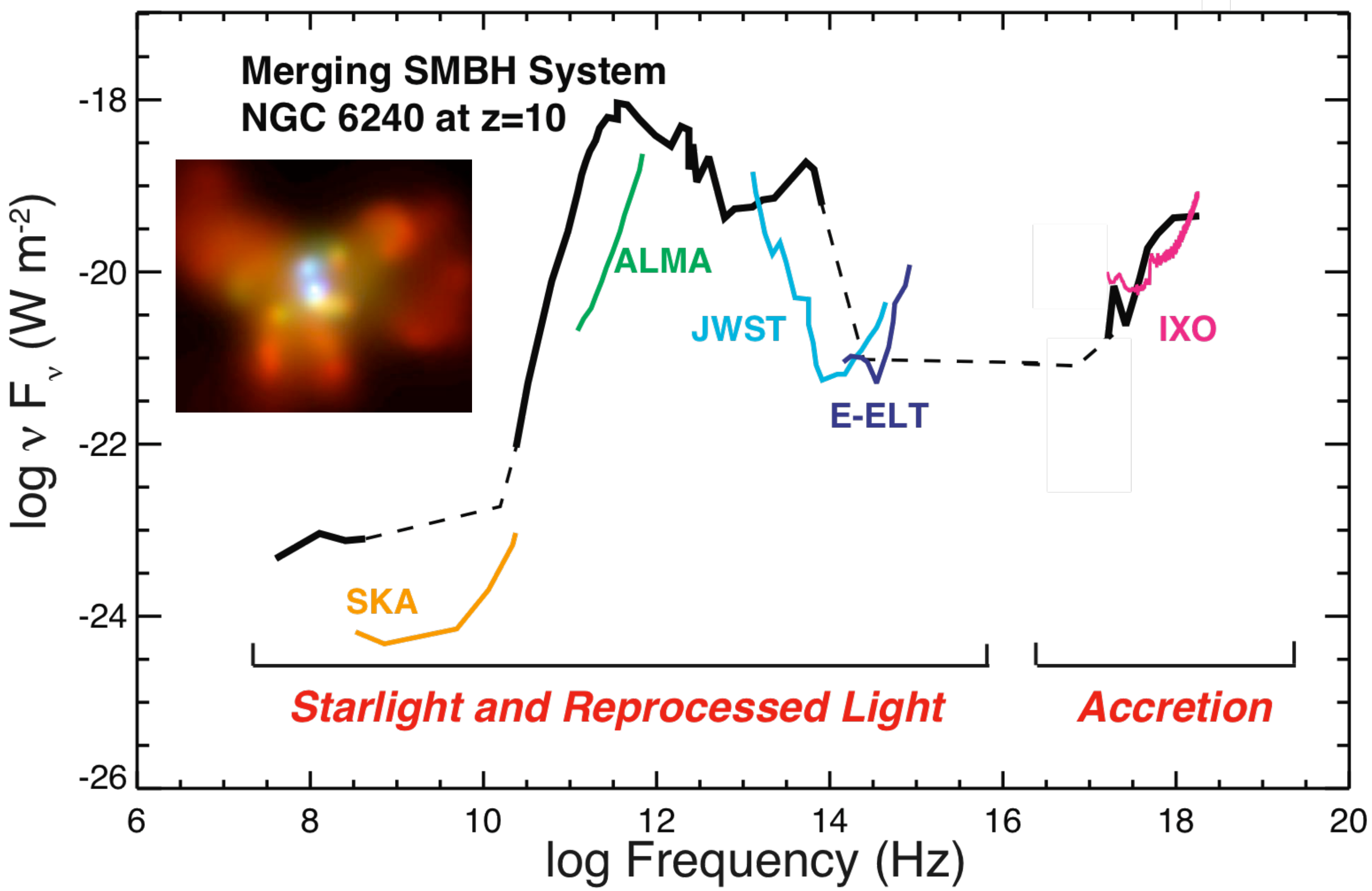


Berti & Volonteri (2008)



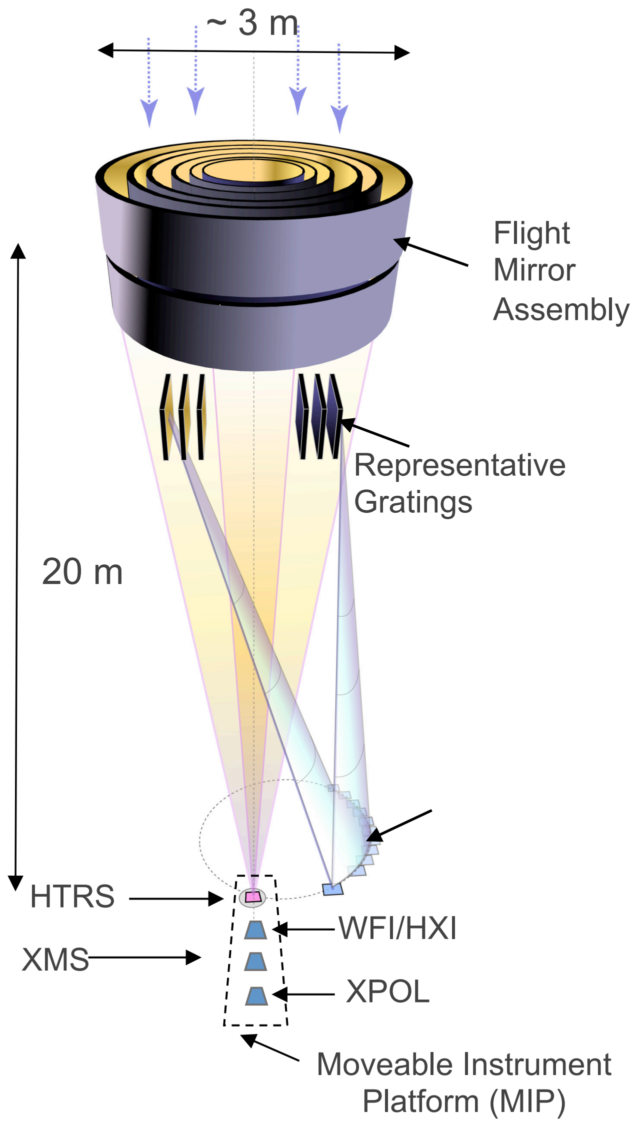
IXO will use the relativistic Fe K line to determine the black hole spin for 300 AGN within $z < 0.2$ to constrain the SMBH merger history

Merging SMBH's at high redshift with IXO



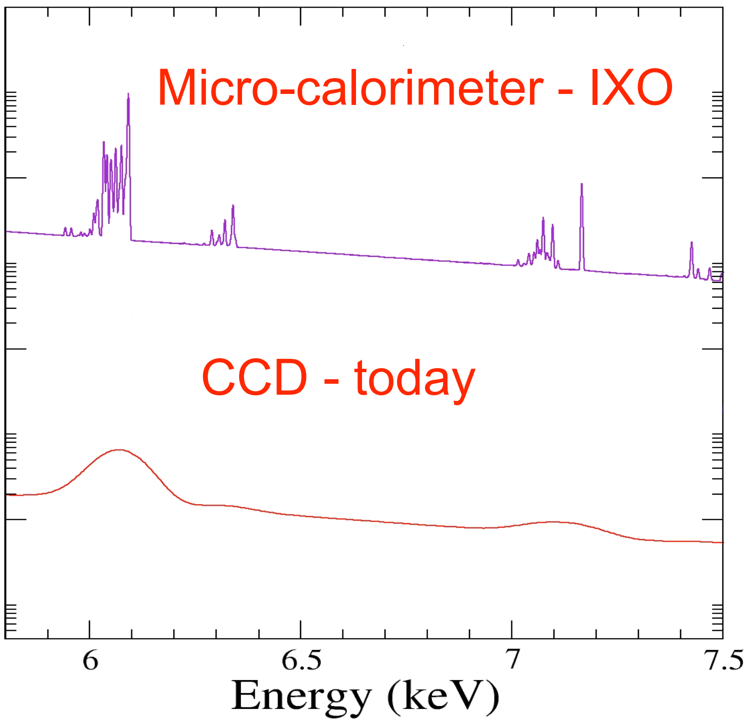
IXO Payload

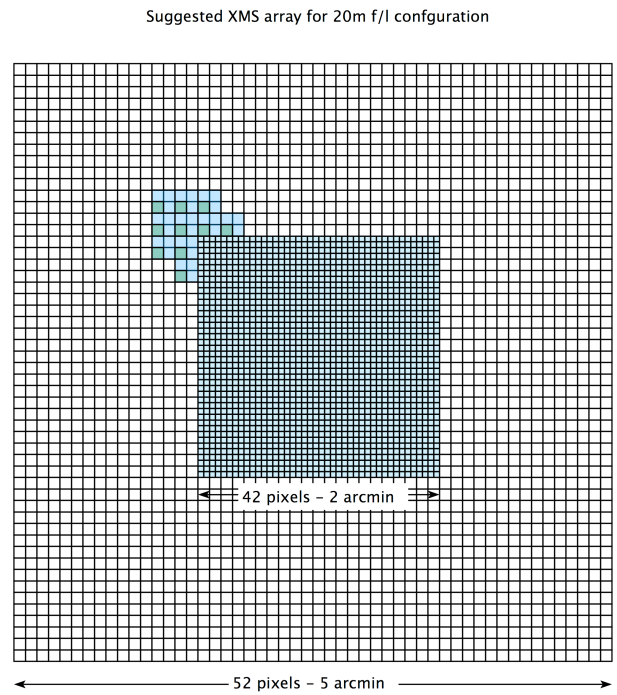
- Flight Mirror Assembly (FMA)
  - Highly nested grazing incidence optics
  - 3 sq m @ 1.25 keV with a 5'' PSF
- Instruments
  - X-ray Micro-calorimeter Spectrometer (XMS)
    - 2.5 eV with 5 arc min FOV
  - X-ray Grating Spectrometer (XGS)
    - R = 3000 with 1,000 sq cm
  - Wide Field Imager (WFI) and Hard X-ray Imager (HXI)
    - 18 arc min FOV with CCD-like resolution
    - 0.3 to 40 keV
  - X-ray Polarimeter (X-POL)
  - High Time Resolution Spectrometer (HTRS)

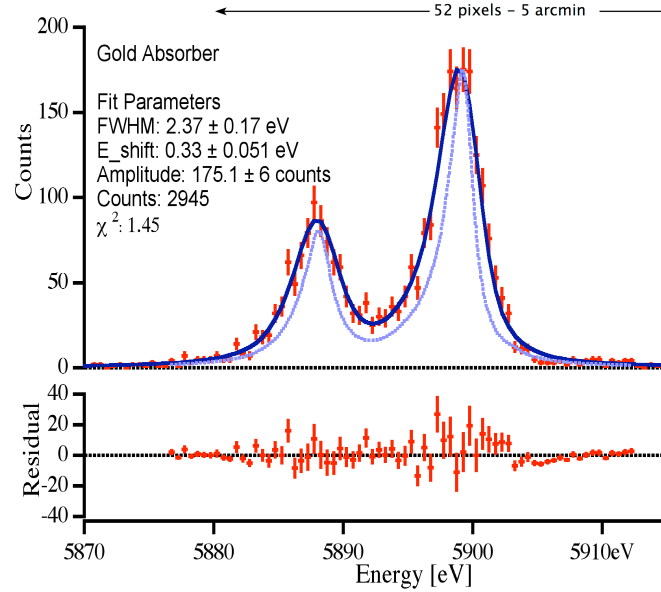


Example of Next Generation Instrument Capability
X-ray Micro-calorimeter Spectrometer (XMS)

- Thermal detection of individual X-ray photons
  - High spectral resolution
  - ΔE very nearly constant with E
  - High intrinsic quantum efficiency
  - Imaging detectors

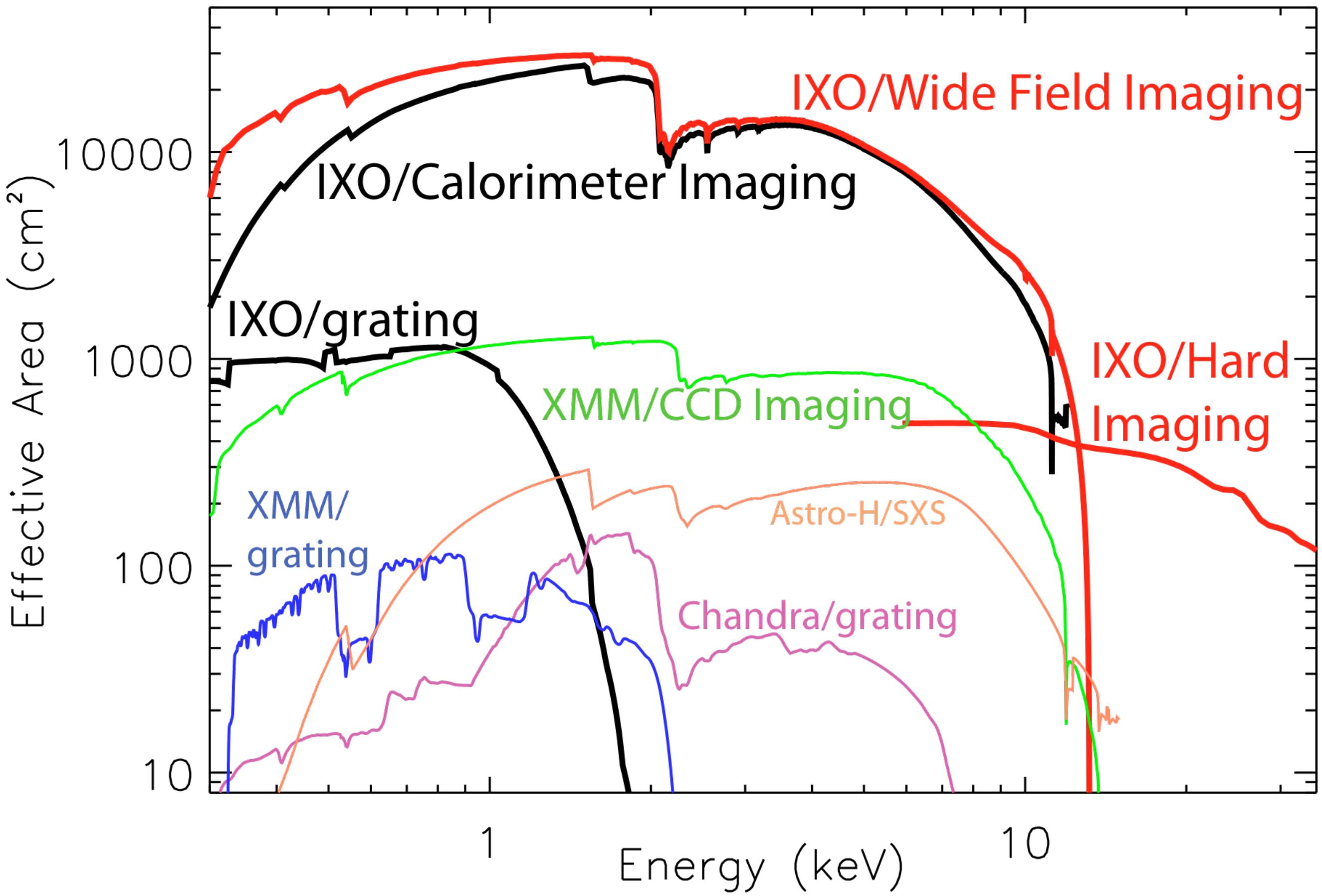






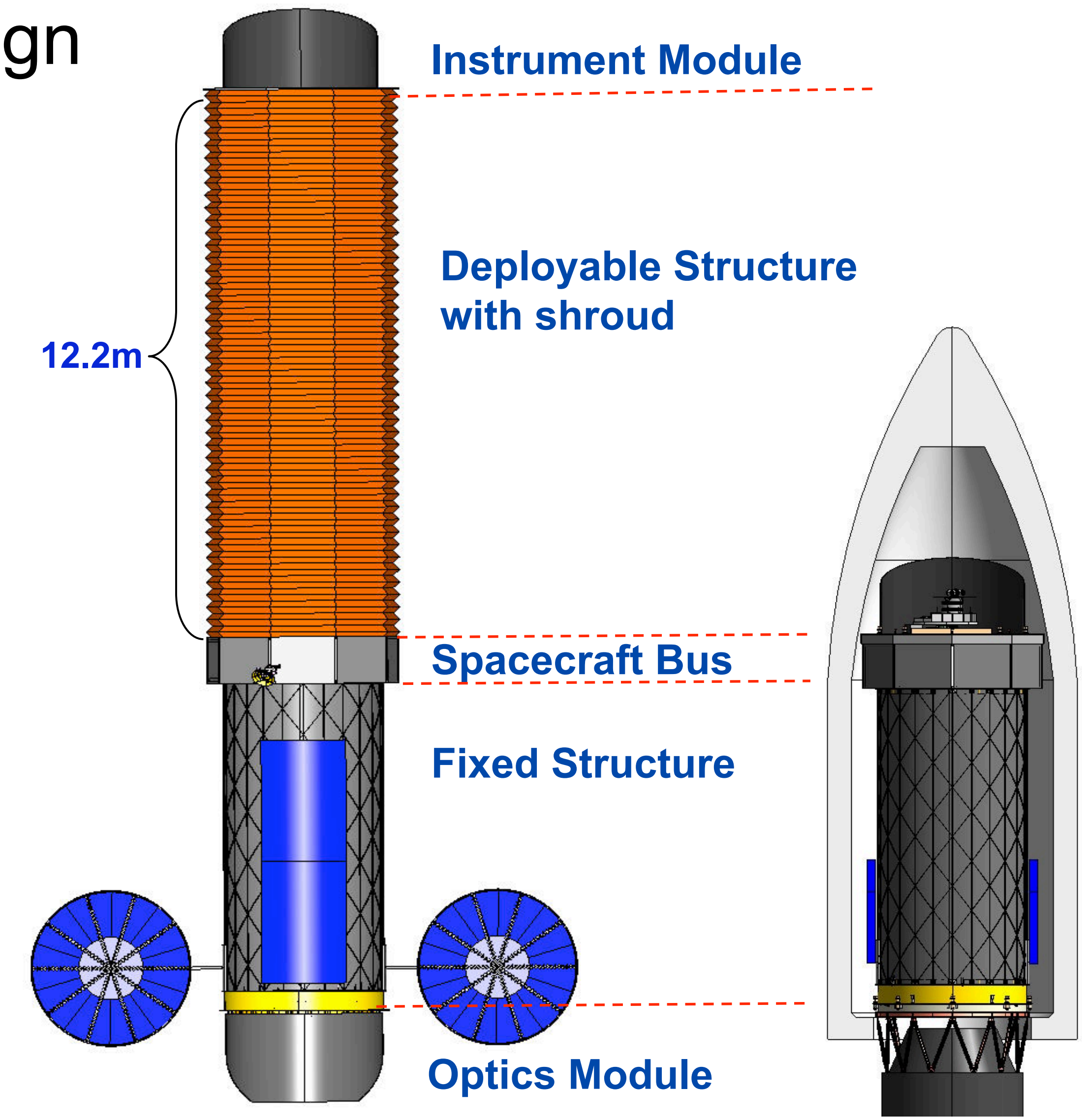
Comparing IXO to Existing Missions

The improvement of IXO relative to current X-ray missions is equivalent to a transition from the 200 inch Palomar telescope to a 20m telescope, and at the same time shifting from spectral band imaging to an integral field spectrograph



NASA Mission Design

- The observatory is deployed to achieve 20 m focal length
- Observatory Mass ~6100 kg (including 30% contingency)
- Launch on an EELV or Ariane V
- Direct launch into an 800,000 km semi-major axis L2 orbit
- 5 year required lifetime, with expendables for 10 year goal



Deployed IXO Configuration

Stowed IXO Configuration

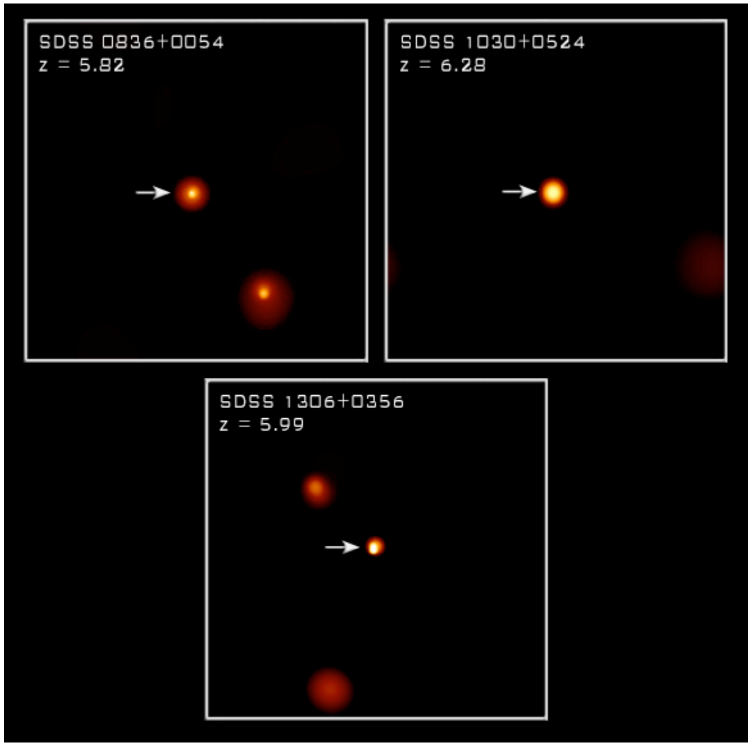
Summary

IXO addresses key and timely questions confronting Astronomy and Astrophysics

IXO will bring a factor of 10 gain in telescope aperture and a factor of 100 increased spectral capability

Studies by ESA, JAXA and NASA demonstrate that the mission implementation for a 2020 launch is feasible with no major show stoppers

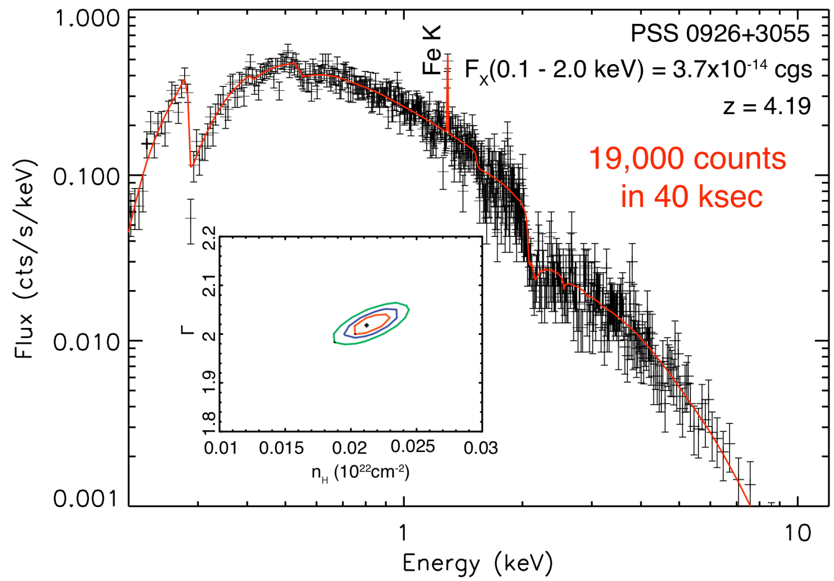
QSOs at high redshift



Chandra has detected X-ray emission from ~100 quasars at $z > 4$

Flux is beyond grasp of XMM-Newton and Chandra high resolution spectrometers, but well within the capabilities of IXO

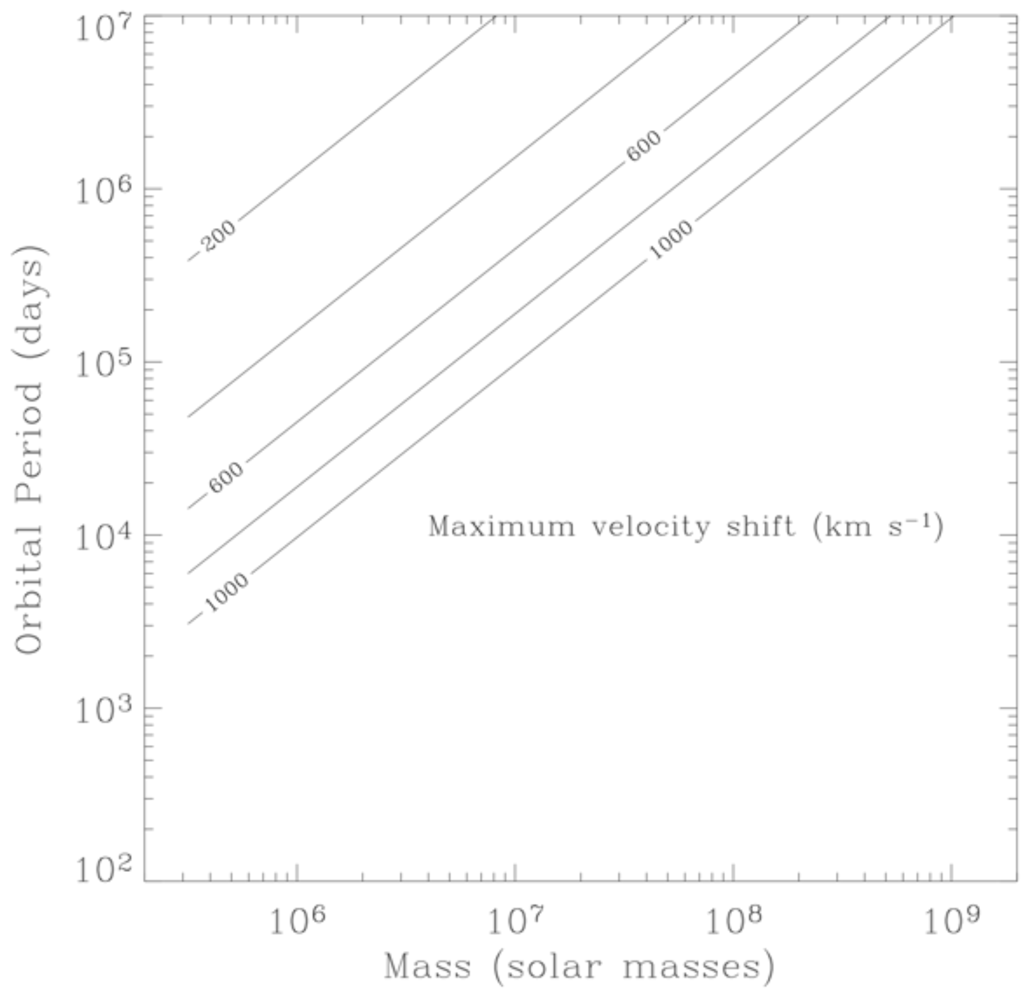
IXO Simulation (40 ks)



X-ray spectra can give:

- redshifts!
- disk ionization
- constraint of L/L_{Edd}

Binary Super-Massive Black Hole Orbits



Key Performance Requirements

Mirror Effective Area	3 m^2 @1.25 keV 0.65 m^2 @ 6 keV with a goal of 1 m^2 150 cm^2 @ 30 keV with a goal of 350 cm^2	Black hole evolution, large scale structure, cosmic feedback, EOS Strong gravity, EOS Cosmic acceleration, strong gravity
Spectral Resolution	ΔE = 2.5 eV within 2 x 2 arc min (0.3 – 7 keV) . ΔE = 10 eV within 5 x 5 arc min (0.3 - 7 keV) ΔE < 150 eV @ 6 keV within 18 arc min diameter (0.1 - 15 keV) $E/\Delta E$ = 3000 from 0.3–1 keV with an area of 1,000 cm^2 with a goal of 3,000 cm^2 for point sources ΔE = 1 keV within 8 x 8 arc min (10 – 40 keV)	Black Hole evolution, Large scale structure Missing baryons using tens of background AGN
Mirror Angular Resolution	≤5 arc sec HPD (0.1 – 7 keV) ≤30 arc sec HPD (7 - 40 keV) with a goal of 5 arc sec	Large scale structure, cosmic feedback, black hole evolution, missing baryons Black hole evolution
Count Rate	1 Crab with >90% throughput. ΔE < 200 eV (0.1 – 15 keV)	Strong gravity, EOS
Polarimetry	1% MDP (3 sigma) on 1 mCrab in 100 ksec (2 - 6 keV)	AGN geometry, strong gravity
Astrometry	1 arcsec at 3σ confidence	Black hole evolution
Absolute Timing	50 μsec	Neutron star studies

IXO Spectral Capability

The IXO energy band contains the K-line transitions of 25 elements Carbon through Zinc allowing simultaneous direct abundance determinations using line-to-continuum ratios, plasma diagnostics and at iron K bulk velocities of 200 km/s